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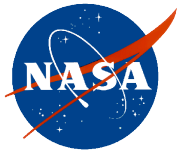
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# **EVALUATING CMIP5 MODELS USING AIRS TROPOSPHERIC AIR TEMPERATURE AND SPECIFIC HUMIDITY CLIMATOLOGY**

Baijun Tian

Eric Fetzer, Brian Kahn, Joao Teixeira, Evan Manning, Thomas Hearty  
and all AIRS team members

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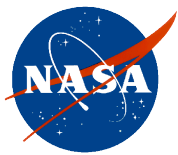
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# Outline

1. Motivation
2. AIRS/CMIP5 Data
3. CMIP5 Models
4. Analysis Methodology
5. Results
6. Summary



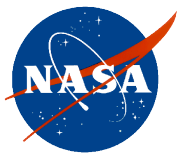
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# CMIP5 and IPCC AR5

- The fifth phase of the Coupled Model Intercomparison Project (CMIP5) involving ~20 climate modeling groups from around the world has produced a state-of-the-art multi-model dataset designed to advance our knowledge of climate variability and climate change (Taylor et al. 2012).
- The next Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR5, scheduled for publication in 2014) will mainly rely on peer reviewed analyses of model outputs from the CMIP5 experiments.
- The CMIP5 model experiments need vigorous evaluation, by comparing the model outputs to the state-of-the-art observations, to quantify the model errors that may lead to climate projection uncertainties. Thus, a wide variety of observationally-based datasets are needed for CMIP5 model evaluation.



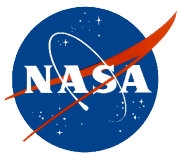
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# obs4MIPs

- NASA and DOE have initiated an obs4MIPs project for CMIP5 model evaluation.
- Obs4MIPs refers to a limited collection of well-established and well-documented datasets that have been organized according to the CMIP5 model output requirements and made available on the PCMDI Earth System Grid (ESG) - Center for Enabling Technologies (ESG-CET) (<http://pcmdi6.llnl.gov/esgcet/>).
- Each Obs4MIPs dataset corresponds to a field that is output in one or more of the CMIP5 experiments. This technical alignment of observational products with climate model output can greatly facilitate model data comparisons.
- obs4MIPs Wiki – <http://obs4mips.llnl.gov:8080/wiki/>



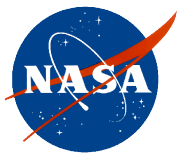
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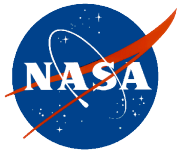
# The AIRS/CMIP5 Dataset

- Monthly averaged air temperature ([ta](#), Kelvin) and specific humidity ([hus](#), kg/kg) from the Version 5 AIRS/AMSU combined retrievals were identified as two of such data sets, and are provided with the following characteristics:
  - For each month from Sept 2002 to May 2011 (time)
  - On a global spatial grid (lon, lat) at 1 degree by 1 degree resolution
  - On the CMIP5 mandatory vertical pressure levels (plev) from 1000 hPa to 300 hPa
- We provide one technical note for each dataset describing strengths/weaknesses, uncertainties, and critical caveats for comparing AIRS data to CMIP5 model outputs.
- The AIRS data have been staged at the JPL/ESG gateway for public access since early 2011, as the first test dataset for the obs4MIPs project.



# AIRS and CMIP5 Models

- The AIRS air temperature, specific humidity, relative humidity data have been used to evaluate climate models, e.g., *Gettelman et al.* [[2006](#)], *Pierce et al.* [[2006](#)] and *John and Soden* [[2007](#)]. These studies mainly focused on CMIP3 models instead of CMIP5 models.
- Recently, *Jiang et al.* [[2012](#)] evaluated the cloud and water vapor simulations in CMIP5 models using the “A-Train” satellite observations including the AIRS specific humidity data. However, they mainly studied CMIP5 model improvement from CMIP3 models as well as CMIP5 model performance relative to observations, including global, tropical, mid-latitude, and high-latitude profiles as well as global spatial correlations and variances expressed as Taylor diagrams. they did not discuss the detailed spatial maps of model hus biases (i.e., model-AIRS) at various vertical levels that are the main topic of this paper. Furthermore, they did not discuss the CMIP5 model simulations of tropospheric air temperature at all.



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# Objectives

- The main purpose of this paper is to compare the tropospheric air temperature and specific humidity climatologies between AIRS, Modern Era Retrospective analysis for Research and Applications (MERRA), and CMIP5 model simulations for data validation and CMIP5 model evaluation.



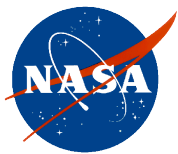
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# MERRA Data

- MERRA monthly mean values of specific humidity ( $q_v$ ) in kg/kg and air temperature ( $t$ ) in K from the MERRA history collection “MAIMCPASM” files, a monthly version of the “MAI3CPASM” or “inst3\_3d\_asm\_Cp”. These MERRA files contain instantaneous basic assimilated fields from the Incremental Analysis Update (IAU) corrector on 42 vertical pressure levels from 1000 to 0.1 hPa, at a reduced resolution spatial grid (i.e., 288-longitude  $\times$  144-latitude with  $1.25^\circ$  by  $1.25^\circ$  resolution).



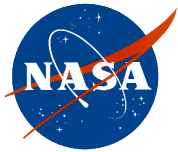
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# 16 CMIP5 Models

#	Modeling Center (or Group)	Institution ID	Model Name	Type	Horizontal Resolution	Vertical Resolution	Reference
1	Beijing Climate Center, China Meteorological Administration	BCC	BCC-CSM1.1	ESM	2.8°X2.8° (T42L26)	17 standard pressure levels	Wu et al. (2011)
2	Canadian Center for Climate Modeling and Analysis, Canada	CCCMA	CanESM2	ESM	2.8°X2.8° (T63L35)	22 pressure levels (17 std + 5 ext)	Arora et al. (2011)
3	National Center for Atmospheric Research	NCAR	CCSM4	AOGCM	1.25°X0.9°	17 standard pressure levels (L26)	Gent et al. (2011)
4	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	CNRM-CERFACS	CNRM-CM5	AOGCM	1.4°X1.4° (T127L31)	17 standard pressure levels	Voltaire et al. (2011)
5	Australian Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence	CSIRO-QCCCE	CSIRO-Mk3-6-0	AOGCM	1.875°X1.875° (T63)	17 standard pressure levels (L18)	Rotstayn et al. (2010)
6	NOAA Geophysical Fluid Dynamics Laboratory	NOAA GFDL	GFDL-CM3	AOGCM	2.5°X2.0°	23 pressure levels (17 std + 6 ext)	Griffles et al. (2011)
7	NASA Goddard Institute for Space Studies	NASA GISS	GISS-E2-H	AOGCM	2.5°X2.0°	17 standard pressure levels (L40)	
8	NASA Goddard Institute for Space Studies	NASA GISS	GISS-E2-R	AOGCM	2.5°X2.0°	17 standard pressure levels (L40)	Schmidt et al. (2006)



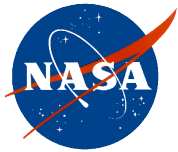
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# 16 CMIP5 Models

#	Modeling Center (or Group)	Institution ID	Model Name	Type	Horizontal Resolution	Vertical Resolution	Reference
9	Met Office Hadley Centre	MOHC	HadGEM2-CC	ESM	1.875°X1.25°	23 pressure levels (17 std + 6 ext)	Jones et al. (2011)
10	Met Office Hadley Centre	MOHC	HadGEM2-ES	ESM	1.875°X1.25°	17 standard pressure levels	Jones et al. (2011)
11	Institut Pierre-Simon Laplace	IPSL	IPSL-CM5A-LR	ESM	3.75°X1.9°	17 standard pressure levels (L39)	
12	Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Atmosphere and Ocean Research Institute (AORI) (The University of Tokyo), and National Institute for Environmental Studies (NIES)	MIROC	MIROC4h	AOGCM	0.56°X0.56° (T213L56)	22 pressure levels (17 std + 5 ext)	Sakamoto et al. (2011)
13	AORI, NIES, and JAMSTEC	MIROC	MIROC-ESM	ESM	2.8°X2.8° (T42L80)	23 pressure levels (17 std + 6 ext)	Watanabe et al. (2011)
14	Max Planck Institute for Meteorology	MPI-M	MPI-ESM-LR	ESM	1.8°X1.8° (T63L47)	25 pressure levels (17 std + 8 ext)	Raddatz et al. (2007)
15	Meteorological Research Institute	MRI	MRI-CGCM3	AOGCM	1.1°X1.1° (T159L48)	23 pressure levels (17 std + 6 ext)	Yukimoto et al. (2011)
16	Norwegian Climate Centre	NCC	NorESM1-M	ESM	2.5°X1.9° (f19L26)	17 standard pressure levels	



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# Comparison Methodology

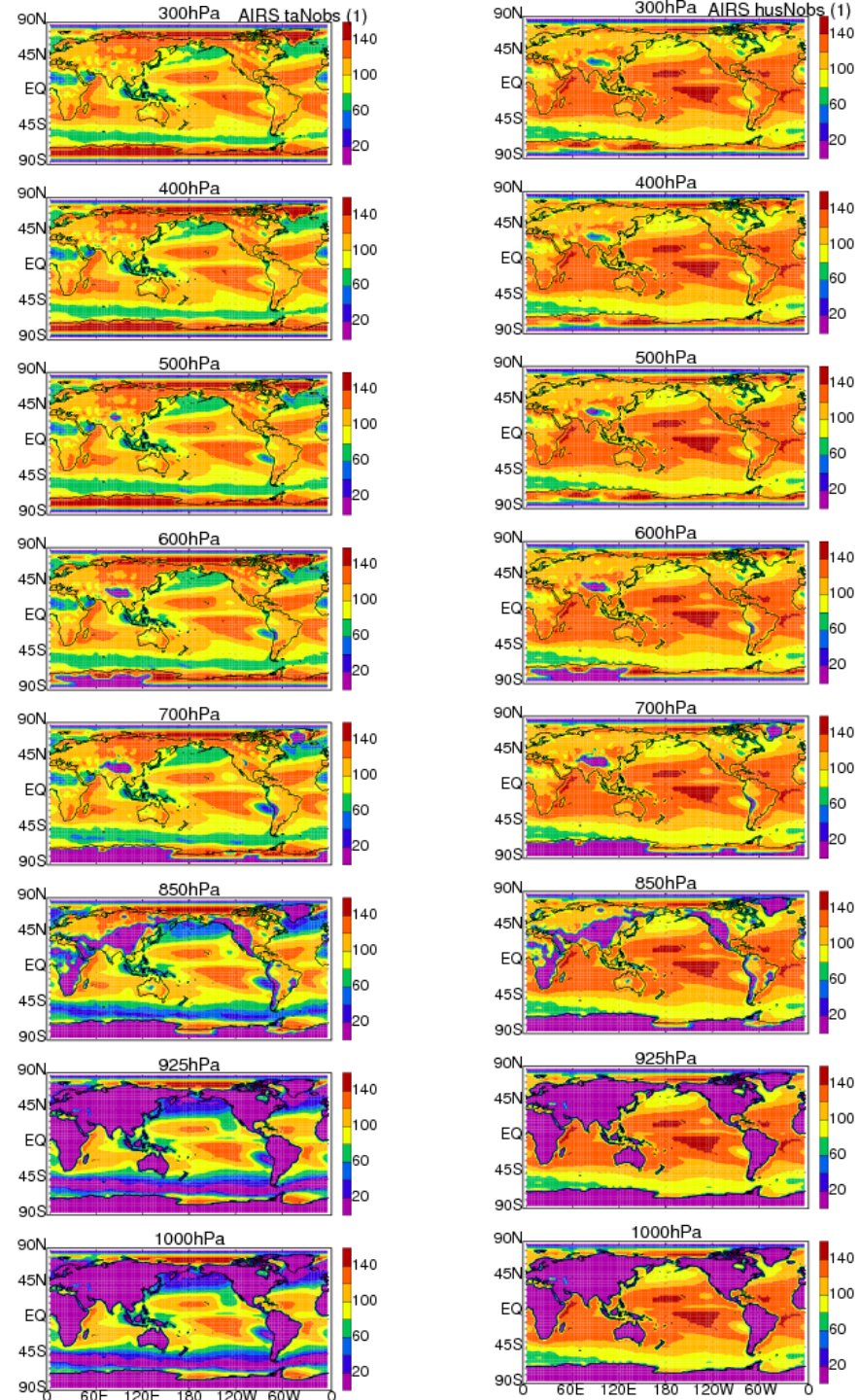
- Climatology from AIRS, MERRA and the multi-model ensemble mean (MMEM) of 16 CMIP5 models
- AIRS and MERRA climatology: 9-year mean (09/2002-05/2011)
- CMIP5 model climatology: 20-year mean (01/1986-12/2005) from historical experiments for each model.
- CMIP5 MMEM climatology: the multi-model ensemble mean (MMEM) of 16 CMIP5 model climatology
- On common spatial grid: 3X3 long-lat grids

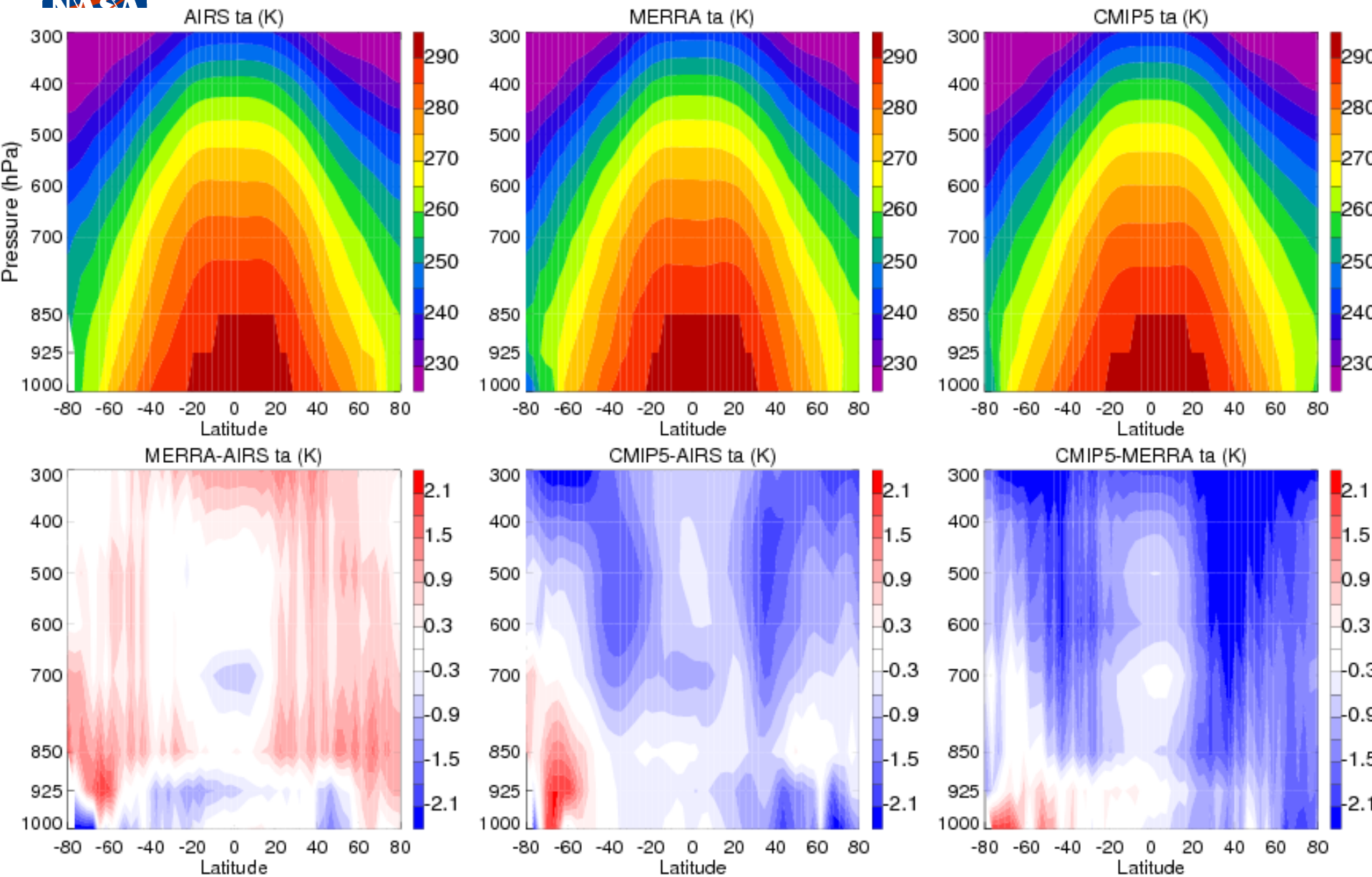


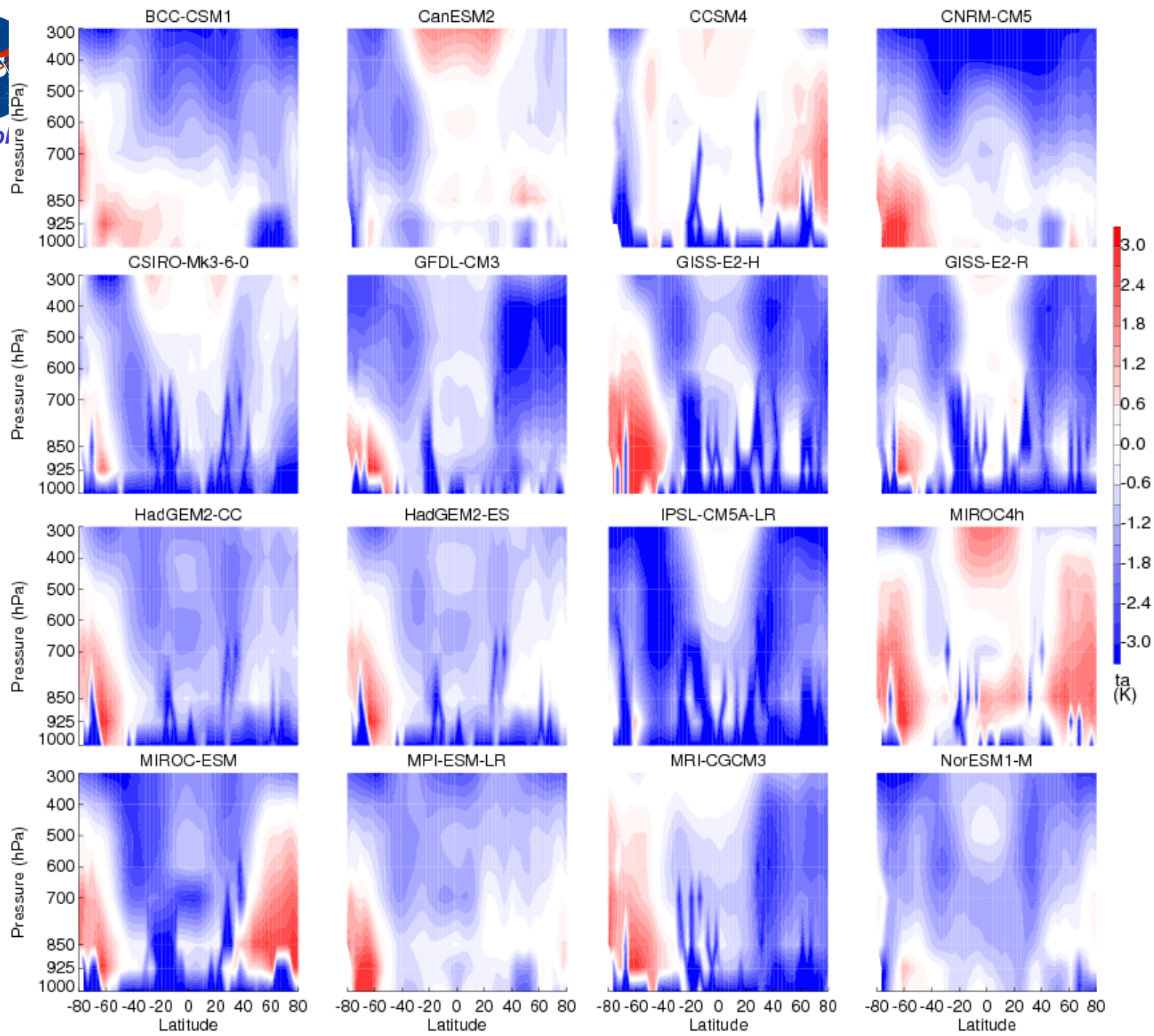
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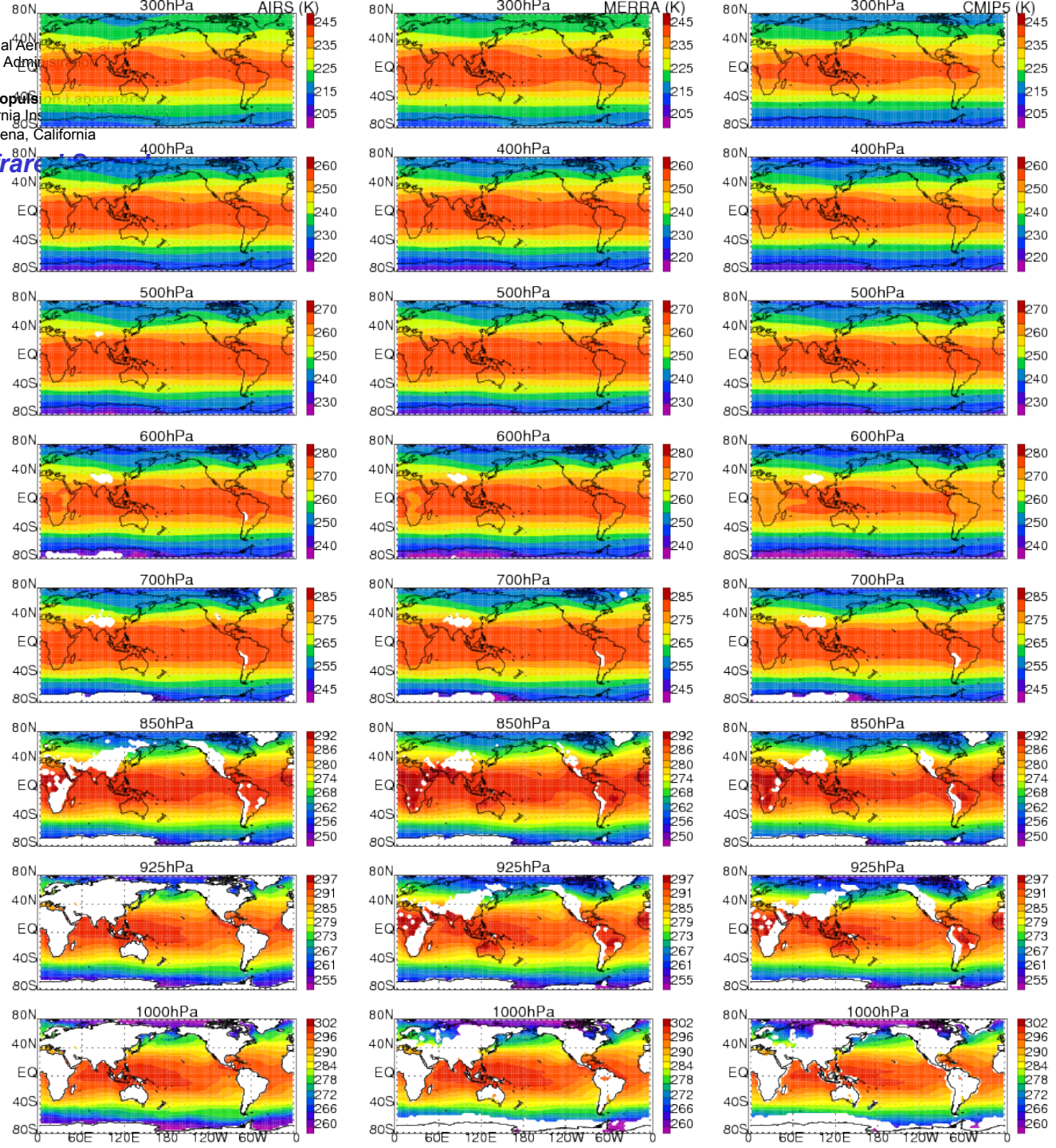






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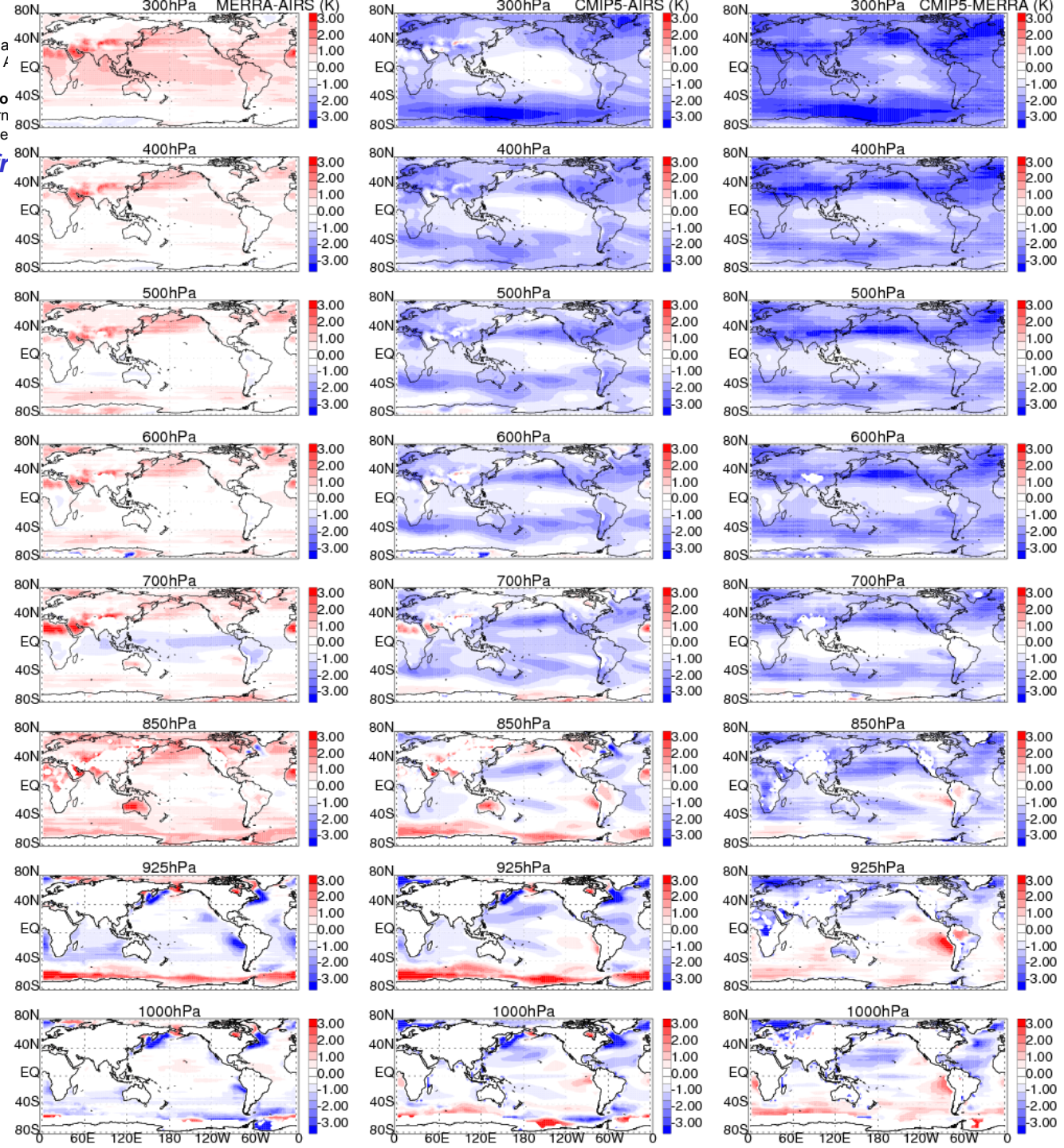
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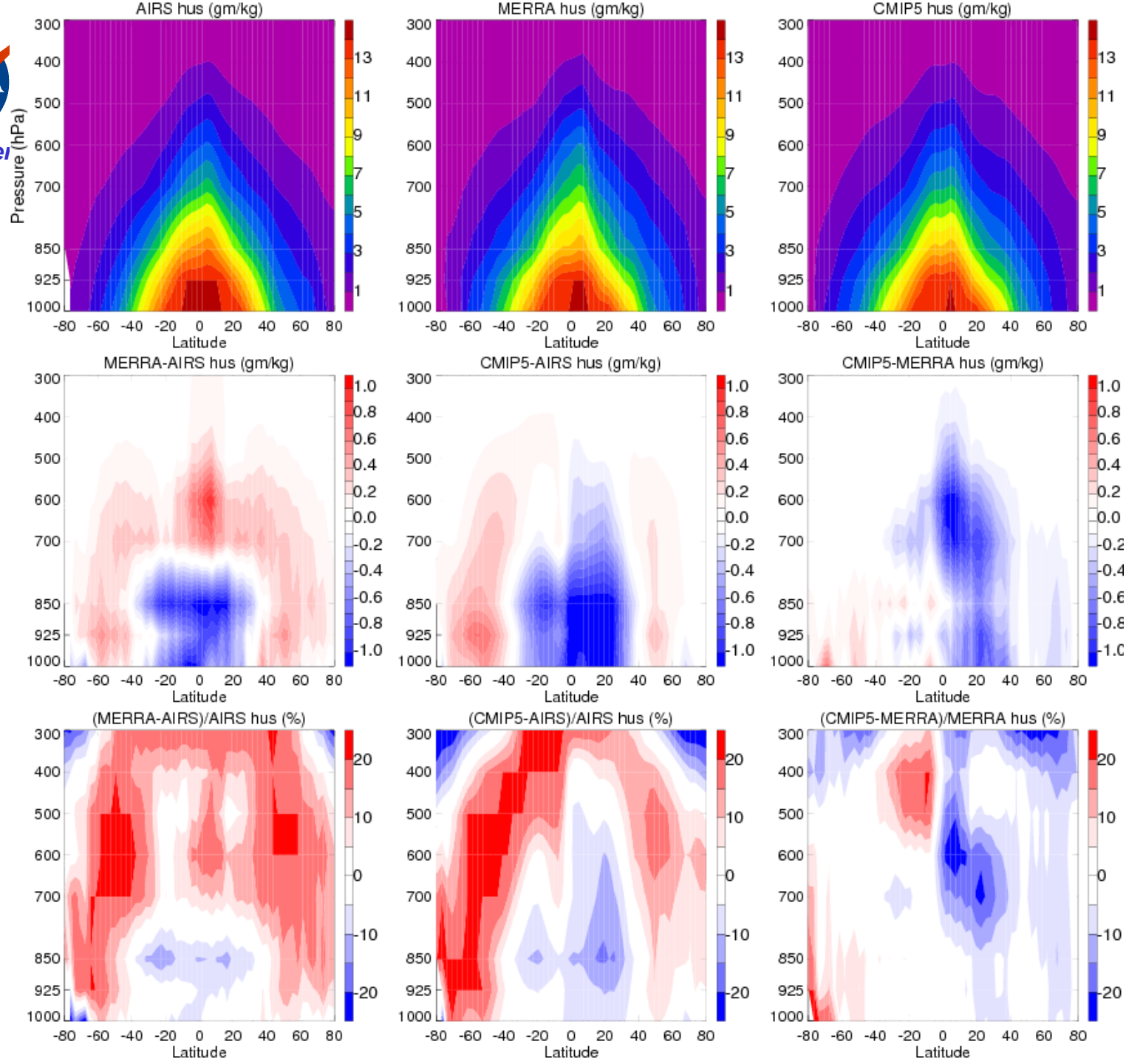




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Atmospheric Infrared

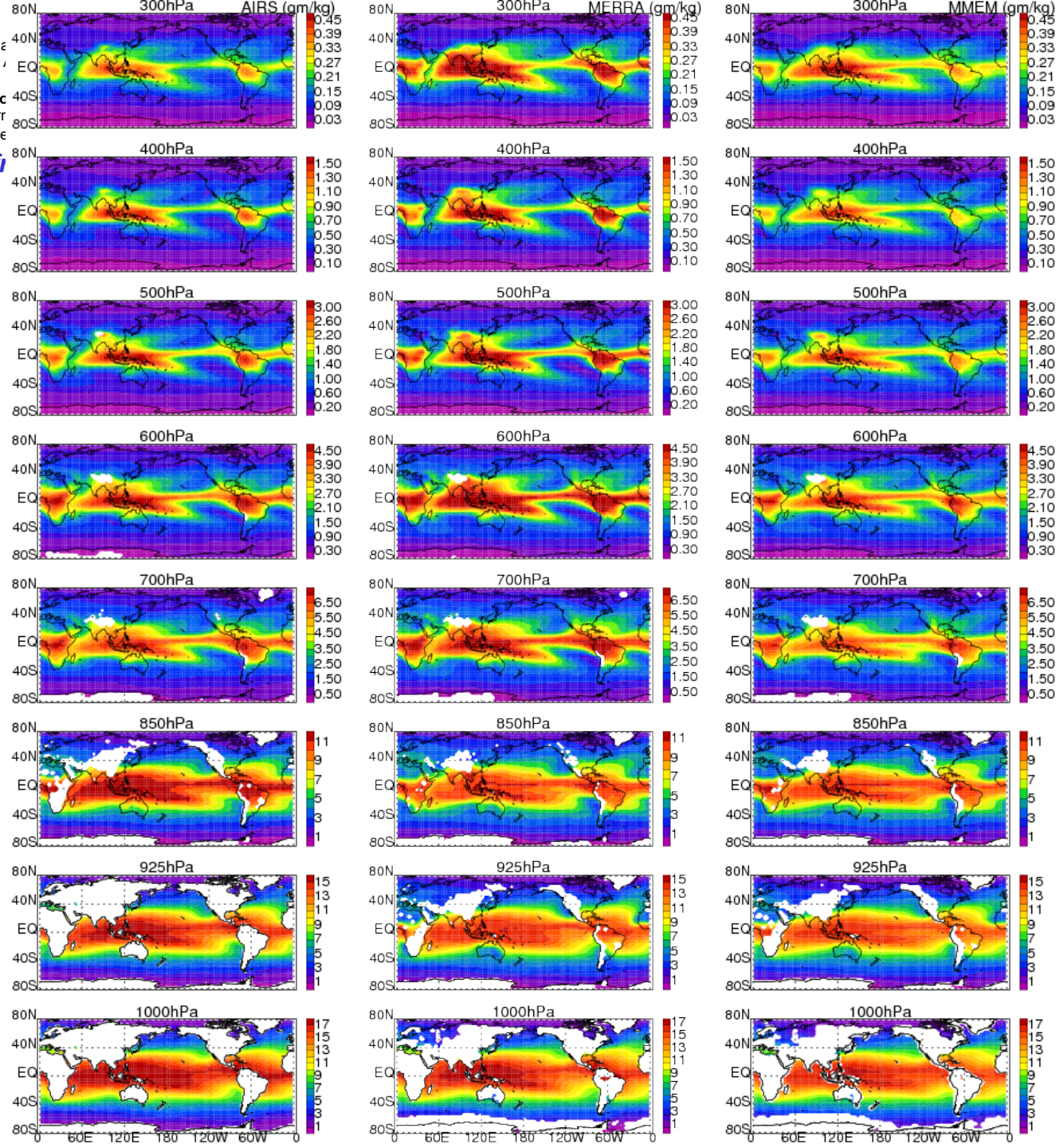






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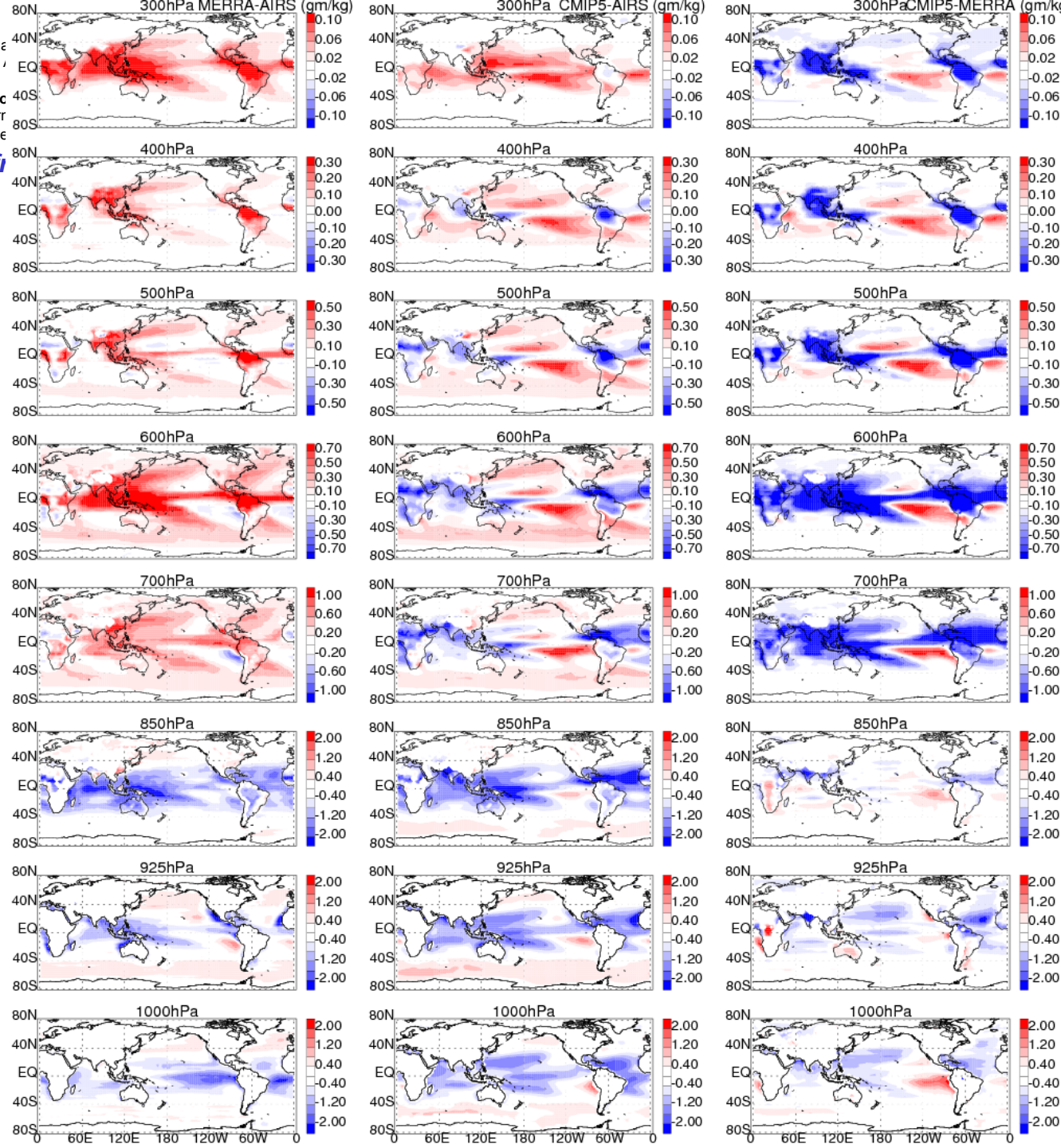
Atmospheric Infrared Experiment





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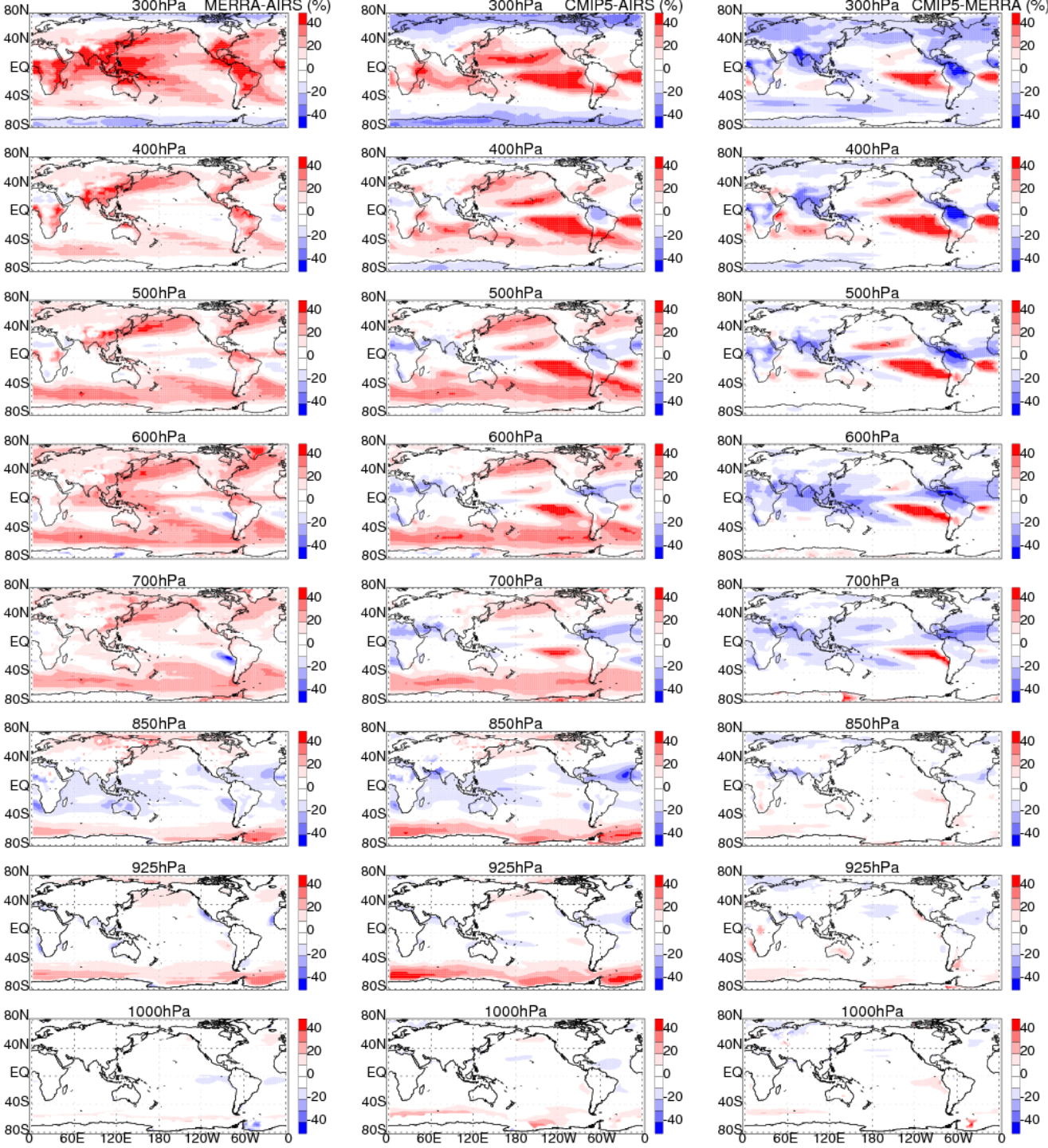
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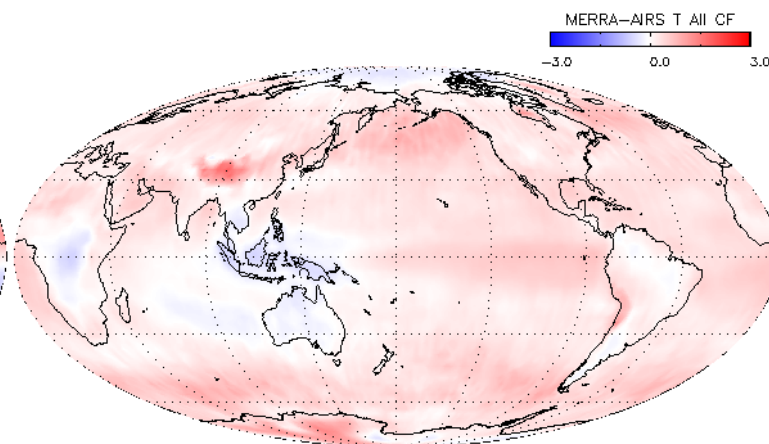
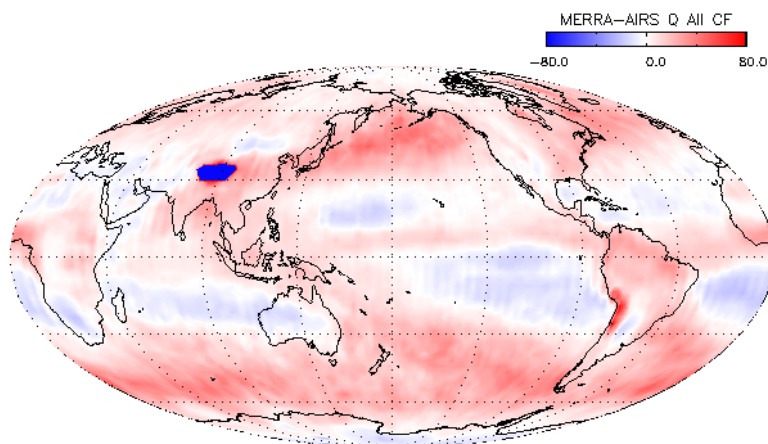
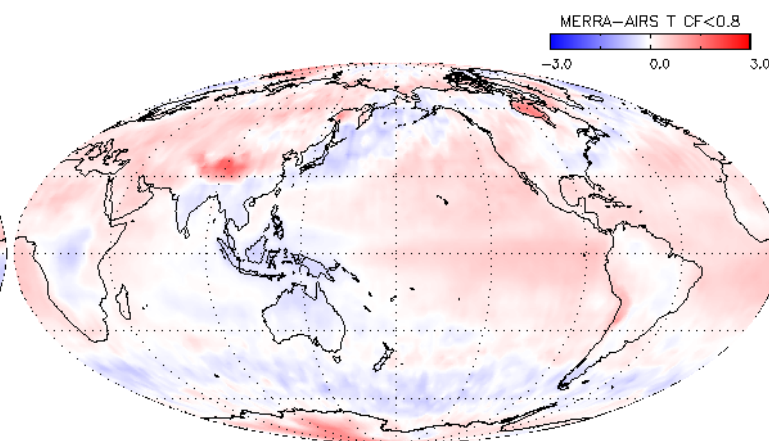
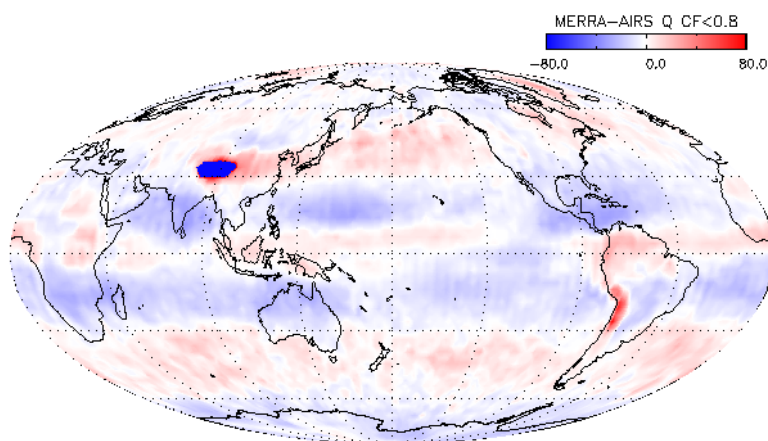
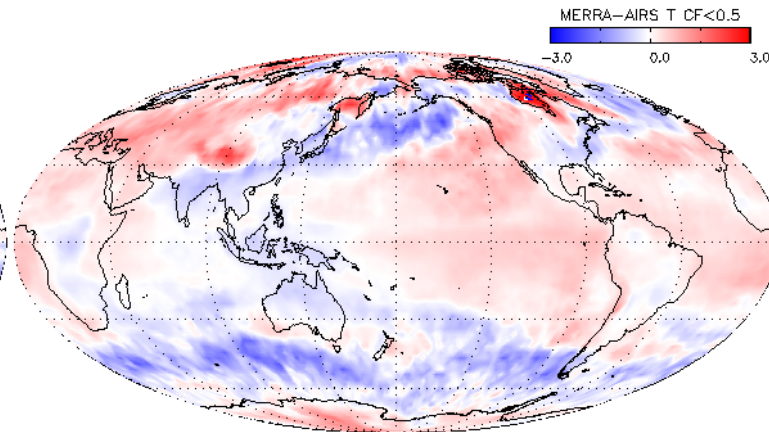
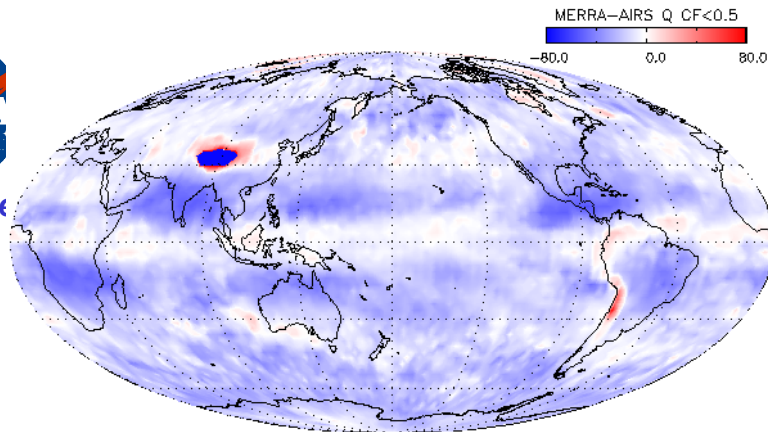




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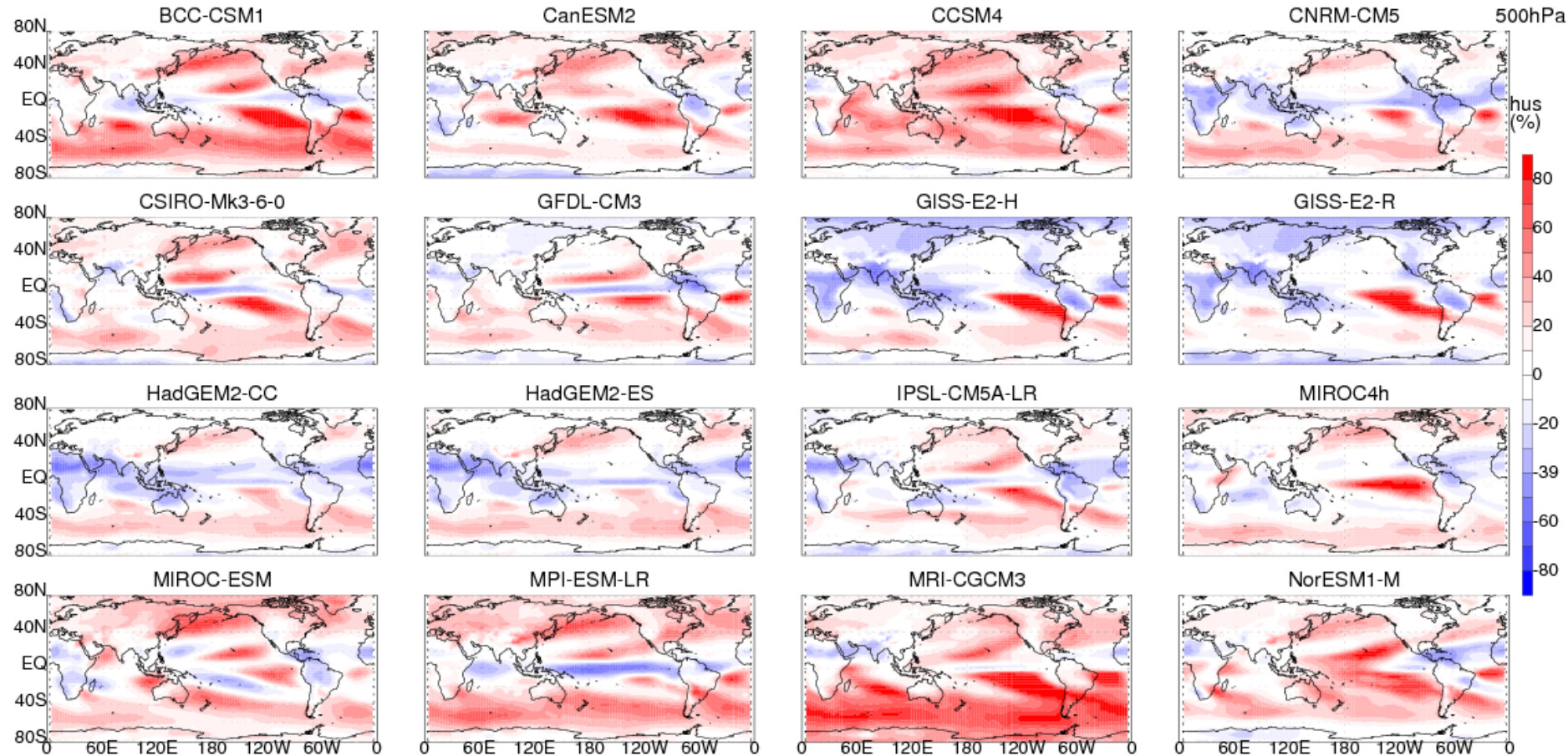


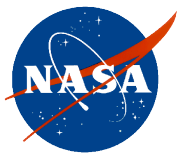


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# Summary

- For the 9-year climatology, AIRS is colder than MERRA in the free troposphere but warmer in the boundary layer with differences typically less than 1 K. AIRS is also wetter ( $\sim 10\%$ ) than MERRA in the tropical boundary layer but drier ( $\sim 30\%$ ) in the tropical free troposphere and the extratropical troposphere. In particular, the large AIRS-MERRA specific humidity differences are mainly located in the deep convective cloudy regions indicating that the low sampling of AIRS in the cloudy regions may be the main reason for these humidity differences.
- In comparison to AIRS and MERRA, the 16 CMIP5 models can generally reproduce the climatological features of tropospheric air temperature and specific humidity well, but several noticeable biases exist. The models have a tropospheric cold bias (around 2 K), especially in the extratropical upper troposphere, and a double-ITCZ problem in the troposphere from 1000 hPa to 300 hPa, especially in the tropical Pacific. The upper-tropospheric cold bias exists in the most (13 of 16) models, and the double-ITCZ bias is found in all 16 CMIP5 models. Both biases are independent of the reference dataset used (AIRS or MERRA).

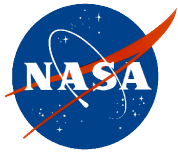


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# Future Work

- ◆ Fully quantify the cloud-induced sampling biases for AIRS  $h_{us}$  and  $t_a$ .
- ◆ Annual cycle, interannual variability
- ◆ Relative humidity

